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Ecological Factors of the Recently Expanding Style of Shifting Cultivation in Southeast Asian Subtropical Areas: Why Could Fallow Periods Be Shortened?

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Abstract

In Southeast Asian subtropical areas, fallow periods of shifting cultivation have shortened, and fallow vegetation has changed from forest to herbaceous meadow. It is widely believed that traditional farming systems have collapsed from the pressure of rising population, but the author considers this doubtful. The author investigated the ecological factors that enabled the newly expanding style of shifting cultivation in Xishuangbanna, Southwest China, to offer a counterargument to the hypothesis that untraditional styles of shifting cultivation are all unsustainable. Nine months after *Eupatorium odoratum* L., a perennial herb that invaded from South America, was removed from fallow fields, the most harmful perennial grass, *Imperata cylindrica* (L.) P. Beauv., was dominant. When water buffaloes were excluded from fallow fields for four years, *Imperata cylindrica* also became dominant. It was concluded that the newly expanding style of shifting cultivation is a rational adaptation to the invasion of the herbaceous perennial plant *Eupatorium odoratum*. Perennial grasses, especially *Imperata cylindrica*, the control of which is the most important factor determining fallow duration, are quickly excluded by the combination of *Eupatorium odoratum* and buffalo grazing. This explains why fallow periods could be shortened. In the farming system observed today, the selective herbicide 2–4–D greatly helps to reduce weeding labors. In addition to ecological factors, easier access to the market has also caused the successive changes in farming systems.

Keywords: *Eupatorium odoratum, Imperata cylindrica*, Jinuo-shan, slash and burn farming, swiddening agriculture, water buffalo, weed control, Xishuangbanna

I Introduction

Shifting cultivation (i. e., swiddening agriculture, slash and burn farming) is the focus of a dispute over whether it constitutes sustainable land use or destruction of the environment. The simple conclusion that traditional methods are sustainable and untraditional methods are destructive is too readily accepted [Linh and Binh 1995; Wang *et al*. 1997]. In the past few decades, the style of shifting cultivation has changed in Southeast Asian subtropical areas. In areas where the greatest change has been observed, fallow periods have shortened, and fallow vegetation has changed from forest to herbaceous meadow,

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whereas in other areas traditional systems remain in place or change is rather slight. Researchers and politicians have proposed that traditional systems have collapsed from population pressure in areas where herbaceous meadow is spreading [Linh and Binh 1995; Wang *et al.* 1997]. Based on this line of persuasion, "untraditional" farmers are often forced to change their approach to agriculture. This paper aims to clarify that recent changes in shifting cultivation are rational responses to ecological factors.

Roder, Phengchanh, and Keoboulapha [1995] revealed that rice yield in shifting cultivation was not related to fallow period length and soil fertility (N P K contents and pH) in North Laos. Rather, the quantity of weeds was related to rice yields [Roder, Phengchanh and Keoboulapha 1997], and fallow length was related to weeding labor [Roder *et al.* 1998]. It is agreed that weed control is the most important factor determining fallow length in Southeast Asian subtropical areas [Roder, Phengchanh and Keoboulapha 1997].

In Southeast Asian subtropical mountain areas, including North Laos, North Vietnam, and Xishuangbanna, Southwest China, until the 1960s, fallow length was 10–30 years, and fallow vegetation was forest [*ibid.* 1997; Yin 1994]. The author consulted Mr. Zhouli (83 years old), Baka-shaozhai, Jinuo-shan, Xishuangbanna, who undertook to explain the history of fallow vegetation. The following local names are expressed in Chinese pinyin. The fallow of the 1st and 2nd years was called "*so peru*," and "*yangcao*"=*Conyza sumatrensis* (Retz.) Walker and "*yi*"=*Imperata cylindrica* (L.) P. Beauv. were common. The fallow of the 3rd to the 6th year was called "*so nu*," and "*lupelu*"=*Colona floribunda* (Wall.) Craib, "*qiazo*"=*Eurya* spp., "*pingala*"=*Melastoma* spp., and *Imperata cylindrica* typically appeared. The fallow of the 7th to the 13th year was called "*so ku*," and was covered with "*susa*"=*Schima wallichii* (DC.) Korth., a tree that grows up to 20 m in height. In the 14th year, the fallow was usually slash-and-burned, and rice was then cultivated for three years.

Recently, fallow length was shortened to five years, and fallow vegetation has become a herbaceous meadow dominated by *Eupatorium odoratum* L. (=*Chromolaena odorata* (L.) King et Rob.) [Roder *et al.* 1995; Furukawa 1997], which originated from South America and spread to the Southeast Asian subtropical areas after the 1950s [Roder *et al.* 1995] (see section II for more detailed descriptions). Why was it possible to shorten fallow periods? This paper demonstrates that the invasion of *Eupatorium odoratum* enabled the establishment of a new style of shifting cultivation involving shorter fallow periods.

II Study Site and Plant Materials

Study Site and Outline of Farming Systems

Field experiments and observations were carried out in Baka-shaozhai, Jinuo-shan, Xishuangbanna, near the Southwest border of China (21°58–59′ N, 101°13–14′ E, 650–810 m alt.). In Jinhong, 42 km from the study site, annual rainfall is 1,221 mm, 89% of which is concentrated in the rainy season from May to October [Yang 1987]. Monthly mean temperatures in Jinhong (540 m alt.) range from 15.5 to 25.5 ℃ [*ibid*.]. Mean temperatures at the study site are estimated from the altitude to be 0.6–1.6 degrees lower. The author first visited this village in December 1998, at which time I observed the farming systems. Field experiments began in August 1999, and were completed in June 2000.

In the present shorter-fallow-period system, after slash-and-burning fallow, the villagers continuously cultivate upland rice for three years, or cultivate rice for two years and cultivate maize in the third year. After harvesting rice in the first and second years, the fields are plowed using water buffaloes (each household keeps 1–3 water buffaloes). After the third year, rice/maize fields are left fallow for five years. Table 1 shows the annual schedule of farmwork.

From May to September, while the crop is growing, water buffaloes are restricted from the fields enclosed by woody fences, which are a mosaic of cultivated fields and fallow fields, and the animals are pastured in semi-primary forests (natural forests slightly affected by human activities: canopy trees include *Hopea, Pometia, Litsea, Lithocarpus, Castanopsis*, etc.). From October to April, the water buffaloes are pastured in the fields. All buffaloes in the village are herded together and allowed to roam, and they move around whole fields, excepting plantations of rubber trees and passion fruits, which are fenced off with barbed wire. Before plowing or removing them from fields, buffaloes in fields are lured back to their owners. Salt, which attracts buffaloes, is used to recall them, though some degree of attachment between buffaloes and their owners is essential.

In rice fields, herbaceous weeds are killed by a selective herbicide, 2–4–D, which kills only non-grass plants, to avoid damaging the rice. According to villagers, the herbicide was introduced to a village for study in 1974. The herbicide is sprayed using hand-pumped spray machines that are positioned on the shoulder. In 1999, 2–4–D was 12 RMB (1 US$＝8.3 RMB) per kg, and 1 kg of herbicide is enough to kill all herbaceous weeds

Table 1 The Annual Schedule of Farmwork in Baka-shaozhai (Solar Calendar)

Month	Farmwork
Jan	Slash the fallow (continued).
Feb	
Mar	Burn the fallow
Apr	
May	Seed rice and maize. Remove buffaloes from the fields.
Jun	Weed by herbicide.
Jul	Weed by hand (rice field) or by hoe (maize field).
Aug	Weed by hand or hoe. Harvest early-ripening rice.
Sep	Harvest rice and maize.
Oct	Harvest late-ripening rice. Introduce buffaloes to the fields.
Nov	
Dec	Slash the fallow. Plow the cultivated fields.

that appear in May and June within cultivated fields of 1 *mu* (15 *mu* = 1 ha). After July, some grasses still remain, and they are removed by hand. Annual grasses without rhizomes can be easily removed, but perennial grasses with rhizomes are difficult to kill.

Weeding is easier in maize fields than in rice fields, because crops are well spaced and hoes can be used. In the fields in which cultivation is exceptionally continued for five years, no rice (i. e., only maize) is cultivated, because the quantity of weeds increases greatly. Notably, maize requires high soil fertility [Watase 1997]. Because the demand for maize is small (usually, it is used for pigs' feed, not for human consumption), such long continuous cultivation is exceptional.

Plants Dominant in Fallows

Eupatorium odoratum is a perennial herb of the family Compositae, which originated from South America and spread to Southeast Asian subtropical areas after the 1950s [Roder *et al*. 1995]. Today, this species is found throughout tropical and sub-tropical areas of the world. The well-branched stems reach 2–3 m in height. The rhizome is absent. Once plants are pulled out or killed by herbicide, no additional shoots emerge. The leaves and stems are toxic to livestock, and water buffaloes kept at the study site did not eat them. The seeds are wind-dispersed.

Imperata cylindrica is a perennial grass (the family Graminae), distributed from temperate to tropical zones in Asia, Africa, and Australia. The plants reach 1–2 m in height. The stems above ground do not develop branching systems. Instead, the underground rhizome is very well developed. This species is extremely difficult to remove because its rhizomes are very capable of regrowth. The best way to control *Imperata cylindrica* is by shading [MacDicken *et al*. 1997]. In the traditional shifting cultivation systems, *Imperata cylindrica* is excluded from the fields by employing tree shaded over long fallow periods of 10 years or more. The seeds are wind-dispersed.

III Methods of Observation and Experiments

Vegetation in Cultivated Fields

In rice fields the first year after burning, the number of individual weeds exceeding 1 cm in height were counted in June 2000 in 10 quadrates (1 × 1 m) before weeding operations began. The number of individual weeds were also counted in maize fields the third year after burning, and in an exceptionally old maize field (fifth year after burning), by the same method. These 30 quadrates were settled along a pass (ca. 3 km) traversing a slope of 20–30 degrees facing South or West, along which rice fields, maize fields, and fallow fields were distributed, forming a mosaic. Ten quadrates settled in an old maize field were restricted to a range of 100 m, because such fields were exceptional. The other 20 quadrates, settled in rice fields and young maize fields, were distributed throughout the traversing pass. According to a farmer, the habitat of the old maize field was not special, because yields and weeding labors in the first to third years after burning were the same as those of the surrounding fields. Thus, the 10 quadrates concentrated within a small area were comparable with the other quadrates.

Vegetation of Fallow Fields under Natural and Controlled Conditions

In the fallows at various stages (first, second, fourth, and fifth years), the coverage of each plant species along five lines (10 m) was measured in June 2000. The coverage was measured at the canopy stratum (the highest continuous crowns of the plant community) and at a lower stratum (20 cm above ground). In the estimation of coverage, the lengths of the lines that were covered with plant crowns were added, and expressed as a percentage of the total length of the line. The lines were distributed in the range of ca. 3 km along the traversing pass noted above, and were settled at a right angle against the pass; i. e., lines were parallel to the slope.

On 24 August 1999, *Eupatorium odoratum* was removed from first year fallows (6 × 6 m, 5 repeats). It is impossible to exclude *Eupatorium odoratum* completely from the fallow, because buried or dispersed seeds germinate if vegetation is cleared during rainy seasons. In this experiment, however, the amount of *Eupatorium odoratum* was greatly reduced. On 4 June 2000, the coverage of plants (%) along the central lines (5 m) of five plots (6 × 6 m) was measured by the method described above. The vegetation was compared with that of the second year fallows under natural conditions.

The effect of buffalo grazing was examined in the following manner. On young rubber plantations, water buffaloes are excluded by barbed wires. The observed plantation was originally a field for shifting cultivation. After rice had been cultivated for three years, rubber trees were planted at intervals of 2.5 m × 5 m. In the sixth or seventh year, tapping begins, and a strong non-selective herbicide, paraquat, will be applied repeatedly so that tapping workers can move among the trees easily. The observed field had been enclosed by barbed wire fencing for four years at the time of observation (June 2000), but herbicides had not yet been applied. Thus, this field was comparable with a fourth year fallow except for the presence of the small crowns of the rubber trees (1.5–2.5 m across). Vegetation of this young rubber plantation was observed by the same method as that used for the fallows under natural conditions, and observations were compared with those of the fourth year fallow. Ideal observation conditions might have included many rubber plantations distributed along the pass where the other observations were made. However, such conditions are not expectable. According to a farmer, the observed rubber plantation used to be an ordinal field for shifting cultivation with emphasis on yields of crops, the labor of weeding and the vegetation of fallow. Thus, comparisons were possible.

IV Results

Vegetation of Cultivated Fields

In June, young herbs (The dominant species was *Ageratum conyzoides* L., and *Eupatorium odoratum* was included) and annual grasses (*Paspalum conjugatum* Berg., *Digitaria ciliaris* (Retz.) Koel.), all of which germinate in May (beginning of the rainy season), were found in rice and maize fields, but few perennial grasses were found (Fig. 1). In October (still in the rainy season and just after the harvest), a number of weed seedlings again emerged, but these, with the exception of some perennial plants with rhizomes, were killed by plowing in December. During the dry season, from December until April, few weed seedlings emerged. In the exceptional case that cultivation was continued for five years, perennial grasses, especially *Imperata cylindrica*, appeared (Fig. 1).

Vegetation of Fallow Fields

The first year fallow was covered with various plants that germinate in October, including annual herbs (*Conyza sumatrensis*), perennial herbs (*Eupatorium odoratum*), and perennial grasses (*Imperata cylindrica, Isachne albens* Trin.). In the second year fallow, annual herbs mostly disappeared, and species diversity decreased; in lieu of this diversity, *Eupatorium odoratum* dominated. Toward the older fallows, *Imperata cylindrica* decreased, and the dominance of *Eupatorium odoratum* was conspicuous. Some tree saplings

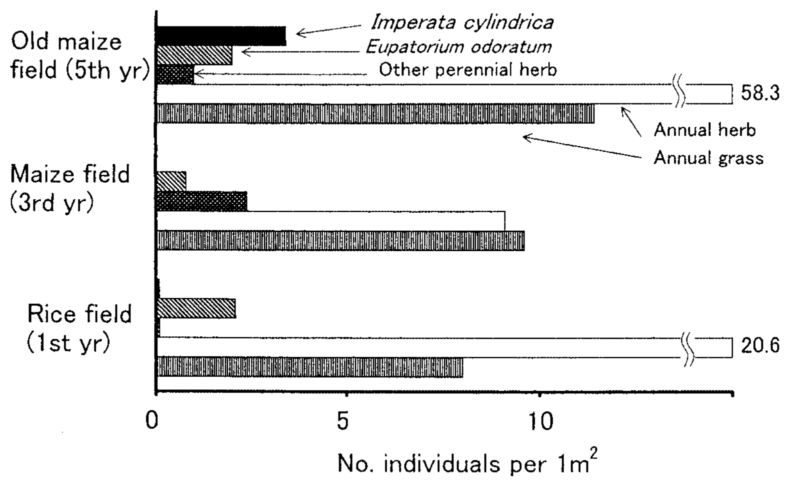

Fig. 1 Vegetation in Early June of Cultivated Fields at Various Stages

Note: Mean numbers of plant individuals exceeding 1 cm in height in 10 quadrates (1 × 1 m) in rice fields (first year after burning), maize fields (third year after burning), and an old maize field (fifth year after burning), respectively, are shown.

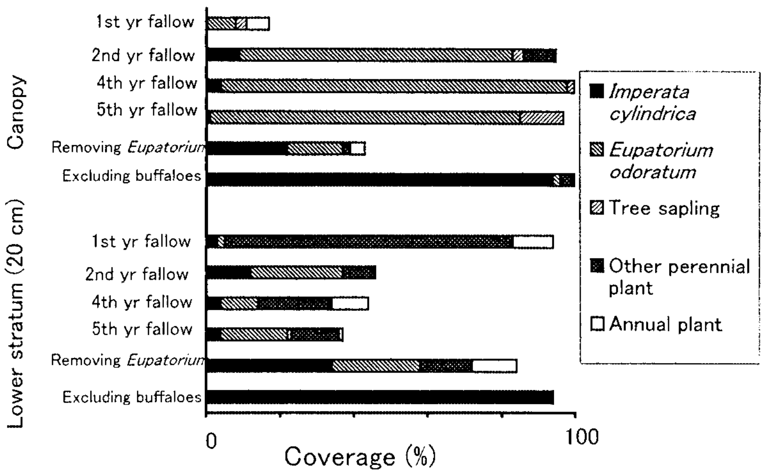

Fig. 2 Vegetation in Early June of Fallows at Various Stages and Experimental Plots

Note: In fallows at various stages and on the young rubber tree plantation from which water buffaloes were excluded (see text for details), mean coverage by plants (%) along five lines (10 m) is shown. In the experimental plots from which *Eupatorium odoratum* was removed nine months before observations (see text for details), mean coverage of plants (%) along the central lines (5 m) of five plots (6 × 6 m) is shown.

became established (Fig. 2).

The fallow vegetation was completely different in plots in which *Eupatorium odoratum* had been removed; as a result of its removal, *Imperata cylindrica* was dominant unlike the second year fallow under the natural condition (Fig. 2). The mean coverage of *Imperata cylindrica* in the canopy strata was 9% (SE 2.2) in the second year fallow, and was increased to 22% (SE 8.4) in *Eupatorium*-removed plots. The difference was significant (U test, $U=2$, $p< 0.05$). This experiment suggests that these two species, *Eupatorium odoratum* and *Imperata cylindrica*, are competitive, and that the former reduces the dominance of the latter in the fallow. This explains why *Imperata cylindrica* can be excluded quickly from the fields, without a long fallow period.

A difference in fallow vegetation between plots in which *Eupatorium odoratum* was present was observed to be dependent on buffalo grazing. Young rubber plantations from which water buffaloes had been excluded for four years were dominated by *Imperata cylindrica* (Fig. 2). The mean coverage of *Imperata cylindrica* in the fourth year fallow was 4% (SE 8.9), and was increased to 94% (SE 5.5) in the young rubber plantation. The difference between values was significant (U test, $U=0$, $p< 0.01$). Water buffaloes do not feed on *Eupatorium odoratum*; they prefer Graminae, including *Imperata cylindrica*. This result suggests that without buffalo grazing, *Eupatorium odoratum* cannot suppress *Imperata cylindrica*. However, as indicated by the experiment in which *Eupatorium* *odoratum* was reduced, the buffaloes themselves do not eradicate *Imperata cylindrica*, because they graze only the leaf blades. Clearly, *Eupatorium odoratum* gains some competitive advantage from buffalo grazing and quickly suppresses *Imperata cylindrica*. Thus, both *Eupatorium odoratum* and buffalo grazing are necessary in the new shifting cultivation system.

V Discussion

Although *Eupatorium odoratum* is regarded as a noxious weed in India [Kushwaha, Ramakrishnan, and Tripathi 1981], Roder *et al.* [1995] revealed, based on questionnaires, that in Southeast Asian subtropical areas farmers prefer it as a fallow plant. To the best of my knowledge, this report constitutes the first evidence of the relationship among the newly expanding style of shifting cultivation, invasion of *Eupatorium odoratum*, and buffalo grazing.

Researchers and politicians have suggested that traditional sustainable shifting cultivation systems have collapsed because of population pressures [Linh and Binh 1995; Wang *et al.* 1997]. However, the distribution of this new style of shifting cultivation is not restricted to areas with high population density, but, rather, is often found in areas where natural forests still remain, such as Baka-shaozhai. Although some natural forests near Baka-shaozhai are protected, other forests are registered as farms and *sharen* (*Amomum villosum* Lour.) is often cultivated in extensive ways (*sharen* plants are patchily distributed in forest floors, but lands are not fully covered with them). Such forests can be transformed to fields for shifting cultivation, and actually, some farmers open forests of small areas, which are added to shifting cultivation fields. However, because demands on lands for shifting cultivation are not strong, non-protected forests are still remaining.

Even without population pressure, villagers have motivation to shorten the fallow period. If they employ long fallow periods, they must commute to distant fields. According to villagers, it sometimes used to take several hours to traverse the distance between the villages and the farthest fields. Logically, if environmental conditions permit, people would prefer shorter fallow periods. In Southeast Asian subtropical areas, the invasion of *Eupatorium odoratum* was an essential change in the environmental conditions that allowed shortening of the fallow periods. In Baka-shaozhai, the new shifting cultivation systems have continued for more than 30 years (four cycles). No evidence of land degradation has been found, and rice yield has been as high as that of upland rice (3–4 tons per ha, according to interviews with 10 farmers. Most Chinese farmers, including ethnic minorities, know the precise area and yield of their lands). However, overgeneralizing from this conclusion might be dangerous. There is a possibility that further shortening of fallow periods will result in land degradation.

Although the short fallow system with herbaceous meadow is common in Southeast

Asian subtropical areas, other types of fallow vegetation and crop-fallow cycles are also found [Yin 1994]. Fallow systems may be partly related to climatic and geological conditions. In addition, methods and intensities of pasturage have great influences on present shifting cultivation systems. In Baka-shaozhai, water buffaloes are introduced to fields in dry seasons (October to April). Before plowing fields or excluding the buffaloes from them, owners must locate the animals and retrieve them. This method of pasturage has a long tradition, and it enabled the establishment of short fallow systems when *Eupatorium odoratum* invaded.

Recently, methods of improved fallow management based on farmers' trials have been reported. For example, seeds of shrubby legume are broadcast in fallows in Northern Laos [Roder and Maniphone 1998]. Similarly, seeds of alder (*Alnus neparensis*) are broadcast in Nujian, Yunnan [Yin 1994] and in Wenshan, Yunnan [Momose 2001]. This study demonstrated that improved fallow management based on invading plants and on traditional livestock is also possible.

Since 1974, the selective herbicide 2–4–D has been used. According to farmers, although this herbicide greatly contributed to the reduction of weeding labor, short fallow systems were possible even before its introduction. This is understandable, given that *Eupatorium odoratum*, unlike *Imperata cylindrica*, does not have rhizome systems and is easy to kill.

However, in the current farming system, another reason *Eupatorium odoratum* is not noxious is that 2–4–D is applied. *Eupatorium odoratum* suppresses grasses, and 2–4–D kills *Eupatorium odoratum* and other herbs, then the rice can grow without competition with these plants. The recent farming system requires capital to purchase herbicide. In the case of Baka-shaozhai, this capital is generated by the collection and sale of mushrooms and butterflies, pig raising, and the cultivation of *sharen* (*Amomum villosum*), passion-fruits, and rubber trees. Thus, not only the invasion of *Eupatorium odoratum*, but easier access to the market has contributed to changes in farming systems.

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